Campus Knights: Situated Pervasive Display as a Window into Pseudo-Immersive Game World

Paula Alavesa, Alexander Samodelkin, Esa Jääskelä, Riku Tanskanen, Bo Li, Timo Ojala and Hannu Kukka
Center for Ubiquitous Computing
University of Oulu, Finland
(firstname.lastname@ee.oulu.fi)

ABSTRACT
In this paper we explore how a situated public display can be employed as a window into pseudo-immersive virtual game world. Our experimental construct is *Campus Knights*, a location based mixed reality game that is played by teams, using mobile phones inside several indoor arenas that have both physical and virtual representations. Each game round begins with players exploring the physical world to recover digital artifacts, and culminates in a *boss fight* inside a 3D virtual replica of the physical game arena. We study the immersive quality of such a physical-virtual game environment in two semi-controlled field trials conducted on a university campus. Our results show that the social aspect of using a public display as a gathering point for players can provide an "in game" alternative for situated game play and enhance social interaction between players in otherwise spatially dispersed game.

Author Keywords
location based games; pervasive games; virtual reality; mobile games; hybrid reality; window on world

ACM Classification Keywords
H.5.m Information interfaces and presentation (e.g., HCI): Miscellaneous

INTRODUCTION
Pervasive games are games that permeate everyday life and living environment. This environment is used as an arena for gameplay, in a way that instead of relying completely on a fictional universe, some elements of the physical world are utilized in the game design [26, 11, 21]. Today, shared public spaces are saturated with ubiquitous computing technologies that offer a wide range of possibilities for creating novel experiences for pervasive gaming, including mobile games that have established themselves as an integral part of our culture [13]. In the study presented here we focus on one such technology, namely pervasive public displays. Public displays of all sizes and varying levels of interactive affordances are a common element in public urban spaces [17], and as such carry significant potential for entertainment and gaming related use cases, especially with pervasive games that can span hours or even days [26, 11, 17].

In this paper we look at using public displays as so-called *window on world* (WoW) [8] for the purpose of creating pseudo-immersive spaces for situated collaborative gameplay. As a research vehicle, we developed *Campus Knights*, a pervasive game that entwines gameplay in physical and virtual spaces. In *CK* the players use the campus for gameplay, but each round in the game culminates in a battle against a final opponent in the virtual arena accessed through a medium sized public display. We collected data through two semi-controlled field trials, where we explore the role of situated displays from the point of view of pervasive spatially dispersed games. We begin by considering related work in the following chapter.

RELATED WORK
Development of displays and head mounted displays has progressed jointly from early days of virtual reality interfaces [31]. Non-stereoscopic displays are still more widely used in accessing both unrealistic and realistic VRs [2, 8]. This approach dubbed as window on world (WoW) or desktop VR has remained as the main interface paradigm for VRs for decades. Emerging technologies such as wearables and mobile AR are technologies to be exploited in the third generation of pervasive games [15], although they have their limitations such as high latency and battery consumption [11]. Very large displays and immersive cave automatic virtual environments (CAVEs) are well-established interfaces for displaying both realistic and unrealistic VRs in games and simulations [24]. However, they are often deployed in restricted (indoor) locations and there may be only one or a few such displays in a given city. In this paper we are particularly interested in medium sized *situated public displays* that have untapped potential as WoW access points to realistic VR environments. Such displays are often found in numbers in several locations in most cities. They are typically connected to Internet, which fuses them into the computing infrastructure of the city and makes them a potential platform for collaborative gaming [17, 32, 23, 20]. While their available computing power may not be capable of rendering high-fidelity VRs, virtual worlds are becoming

more scalable and instead of specific client software they can be now be visualized with web browsers supporting webGL [6]. While game worlds are often unrealistic, situating a game into a realistic virtual environment has been done before, although in these cases virtual environments are typically simplified or depict an alternate historical continuum such is the case with the popular game series *Grand Theft Auto* or *Fallout*.

Typical games for situated public displays are often single player standalone games that are separated from their real-world context either spatially or socially. *Manhattan Story Mashup* (*MSM*) was a collaborative storytelling pervasive game where people in the web created stories and people on the streets of Manhattan competed in illustrating those stories with photos [32]. Completed stories were shown on a large scale display at Times Square for the general public and players. *MSM* showed that displays can have a rewarding and satisfying meaning for the players, although in *MSM* they were not required to get together by the display. *Wordster* is a more recent example of a word game that has been played on public displays. *Wordster* was a success as a single player game but failed in creating a social setting for the mobile multiplayer version [23]. *Martians from Outer Space* is a game that depicts a realistic city scape and utilizes medium sized pervasive displays. It does not fully utilize the social benefits of the platform. Though the players co-operate towards a common goal in the game e.g. try to prevent an alien invasion. The co-operation is scarce as the players engage the game solo by each individual display [12]. However, when a game is presented as a team game from the beginning and no single player option is offered, the players may be more willing to interact like in First Strike. It is a multiplayer war strategy game that is played by public display with a mobile phone. The game was specifically designed to fit the context of a traveler's lounge to enhance social interaction. The game area is restricted but First Strike shows that social interaction and communication can be mediated by public displays. In First Strike the display is used for visualization of game status and the players do not coordinate in a 3D environments by the displays [20]. Coordination and interaction by using mobile phones is however something that is done in many standalone applications and games for displays or projected scenes [32, 34, 18, 4].

Although one of the key elements of pervasive games is social expansion [14] on most location based pervasive games this expansion is quite literal and driven by another depicting feature of pervasive games, spatial expansion. *Geocaching* is one of the oldest location based games and it can disperse the individual players on global scale [28]. In *Ingress*, the players battle on city wide arenas between two factions and though it is a team game and the co-location is encouraged in "capturing portals". The physical world elements utilized in *Ingress* are the portal location that oftentimes are local landmarks. The game however relies in inaccurate locationing hence the players do not need to be physically co-located [3]. The social aspect and connectedness are factors that motivate gaming and keep the players loyal to their game apps [13]. Many location based games lead into scattered players [26, 32, 21]. Even if the players are encouraged to be co-located in the game they do not have to be in order to get the benefits of collaborating. There is varying amount of inaccuracy in the available location data for location based games. This results in mismatch between the real and the perceived location of players [22]. The social aspect of location based games can be a key motivator for the players and co-located gameplay in general is fun for the participants [28, 9]. For these reasons we suggest enhancing city wide pervasive mobile games with the use of public displays. Similar idea has been introduced at a concept level for enhancing offline social interaction [10] and co-located gameplay as was done in *Capture the Campus* [33] that combines real world location capturing and pervasive displays. In the following chapter we describe partly controlled field trials on a game where the use of displays is to promote in game social interaction e.g. co-located interaction during gameplay while also using the displays as WoW access point to virtual campus.

CAMPUS KNIGHTS

Pervasive games have a tradition of utilizing elements of role playing games (RPGs) in game design, ranging from fully implemented digital pervasive live action RPGs to games that only take advantage of some elements of the genre. This has proven to be a good strategy for designing engaging location based games [14, 7, 29]. The predominant story arc of many role playing games is the classical quest, where the hero attempts to recover an item or artifact that will allow him/her to defeat the antagonist of the story. Campus Knights adopts this tried-and-true story vehicle in the gameplay design: a band of heroes has to first explore the physical game arena to discover various artifacts that will enable them to defeat their nemesis, the *evil professor*. The final battle is fought in the virtual world, where the avatars of the players fight with the help of the artifacts they have collected.

CK has three phases, where the level of required collaboration varies: quest phase, capturing a location and *the boss fight*. The players can do the quest phase individually, they can capture locations in teams faster or try to do it alone, but in the end must come together to defeat the final opponent or face a certain failure. Multiple teams can play simultaneously, and in this case the team who locates and defeats the final opponent the most often wins the game round. We had three game arenas available: the entrance floor of the information technology building (A1), the main common area of the university (A2), and a large library (A3). Arenas are each 2000-3000 m^2 in size. They are equipped with a public display that serves as a window into the virtual arena, a collaborative 3D virtual model of the physical arena where the final battle happens. This is accomplished by locating and scanning QR codes with a mobile phone. Completing *chores* yields the players in-game currency to purchase consumable

Figure 1. Available *CK* arenas. The physical arenas on the left column with displays. The virtual arenas on corresponding locations can be seen in the right column.

items like *coffee*, *cheat sheet*, *unbreakable argument*, *etc*. These items give players power ups as they battle in the tournament phase, and are crucial in defeating the final opponent.

Tournaments

The tournament phase consists of two activities: conquering locations and diving into the virtual arena through a situated display to defeat the boss. Players conquer locations through physical presence, and when enough locations have been conquered, the final opponent will appear in the virtual arena. Team participation is encouraged by a mechanism where the number of players entering an arena has an impact on the time needed to conquer it. Finally, players must find the situated display on which the virtual game arena (Figure 1) appears on, navigate it to locate the final opponent, and defeat it in battle (Figure 2).

Players battle the final opponent in the virtual arena using their mobile phones. Once the fight commences, players have six minutes to find and to defeat the opponent. The first player to enter the virtual arena is placed at a given location, and the viewpoint is fixed to her/his first person perspective on the public display. One player controls the navigation around the virtual arena. Once the boss is located, the fight commences. The camera angle shifts to a bird's eye view where each player is represented by an avatar, and important game-related information such as each player's health bar is shown in the upper corner of the display. If the players defeat the boss, they receive a point. If they lose, they have to re-conquer the physical locations to gain again the access to the virtual arena and the boss fight. The rules of the battle are set so that it is impossible for a solo player to beat the boss alone, thus team play is required by design.

Technical Implementation

CK is implemented with a traditional client-server architecture. The mobile game client is implemented atop Android 4.4. The game client provides the controls needed in the quest and tournament phases, including navigation in the virtual arena. The virtual arenas are implemented as 3D scenes atop the realXtend open source game engine [25] and hosted online in the Meshmoon hosting service. The 3D scenes are shown on the public displays with a dedicated 3D viewer software (Meshmoon Rocket) running on the control PC of the public displays. The displays used in the study are 46" full HD LCD panels installed at eye height on movable stances. A dedicated server takes care of game logistics and communication with clients over the Internet. The positioning of the mobile phones is done with A-GPS that benefits from the dense population of public Wi-Fi access points scattered around the campus.

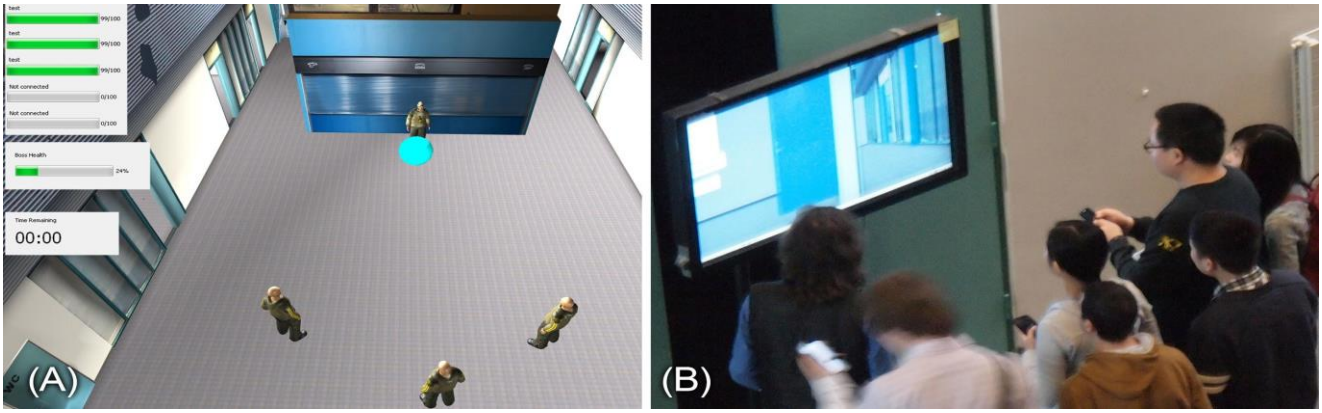

Figure 2. Boss fight about to commence in the virtual arena (A), players playing the game by the display (B)

Figure 3. Example screenshots of the *CK* mobile app: (A) splash screen and log in, (B) selection of items consumable items the players can buy and (C) screen with the controls for moving and fighting in the VR.

Figure 3 shows selected screenshots of the mobile client.

FIELD TRIALS

CK was evaluated in two field trials with slightly varying game parameters. The design and data collection from the experiments was guided by the principles of conducting critical research and the guidelines for evaluating interpretive field studies in information systems [16, 27]. Collected data consists of observations, field notes and answers to the Game Engagement Questionnaire (GEQ) [1]. Players' locations and the use of the mobile game app were logged by the game server.

Field trial 1: Multiple arenas, few chores

The first field trial of Campus Knights spanned two days. During the first day the players got their user IDs and they were allowed to do only the quest phase, and tournament phase was conducted on the second day. In this trial, all three arenas illustrated in Figures 1. and 4. were accessible to the players. Each arena contained one chore and a fourth chore was placed along the route between arenas A1 and A3. In total 9 players (female N=4) aged between 23 and 27 years participated in three teams of three players. All participants were university students, five majoring in computer science and four in other fields.

Field trial 2: One arena, many chores

For the second field trial, the game parameters were modified to include only one arena (Figure 1: A). The number of *chores* inside the arena was increased to 17, and new types of chores where players had to interact with campus staff or complete a kind of scavenger hunt to gain access to the QR codes were added. Participants in this trial were 9 high school students attending an event at the campus (all male). The game lasted 80 minutes in total, where first 15 minutes were used for instructing the players about gameplay.

RESULTS

Player Activity

Figure 4. illustrates the mobility traces collected from the players during the first field trial. As seen in the figure, the players were very active in traversing the available three game arenas in search for the QR codes that would allow them to purchase equipment for the tournament phase on day 2. In field trial 1, where players were allowed to move freely between the 3 game arenas, they were very active in A2 and A1. However, in A3 where the display was slightly hidden (Figure 1: A3) they quickly lost interest and moved to other arenas. This is clearly visible from the paths of their movements (Figure 4).

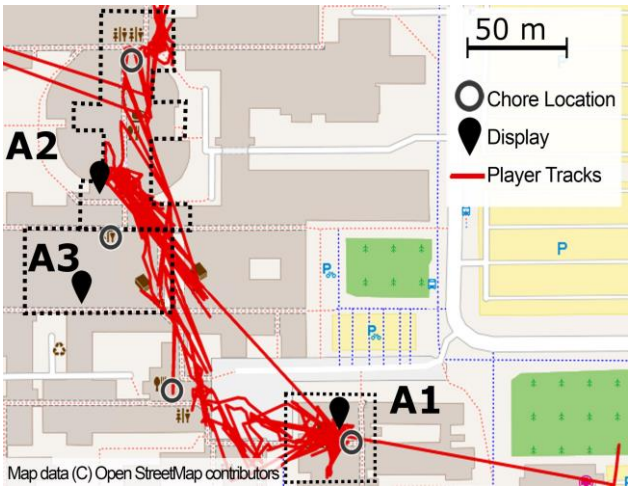

Figure 4. Setup of field trial 1 on our campus. The three arenas are marked with dashed lines.

Figure 5 illustrates player mobility and the game set up during the second field trial. The area corresponds to A1 from the first field trial (Figure A). Though the number of arenas was limited to one, the increased number of *chores* inside the arena ensured that the players remained active, searching for the hidden QR-codes. Player routes in Figure 5. show that chores that were easier to find were more popular than those that were on the outskirts of the arena.

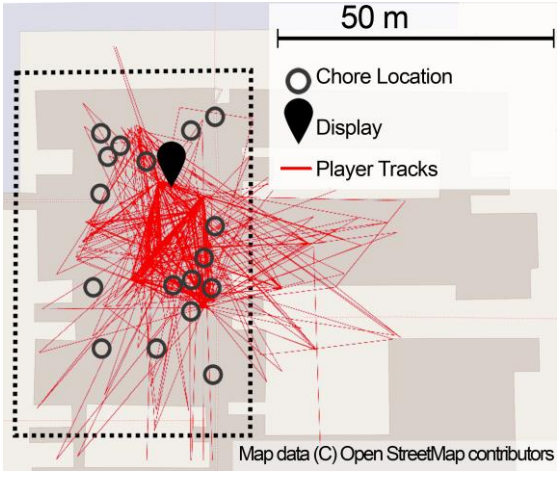

Figure 5. Setup of field trial 2. The route is based on 600 coordinate pairs logged in the midpoint of the trial 2.

We also collected quantitative data from both field trials. Though the number of players was the same in both trials, the increased number of chores in field trial 2 led to significantly greater activity from the players (25 chores complete in field trial 1 vs. 63 in field trial 2).

	Chores completed	Boss fights (lost/won)	Locations conquered	Items bought
Field trial 1 (player N=9)				
A1	10	8 (7/1)	35	25
A2	7	3 (2/1)	15	
A3	8	0 (0/0)	17	
Total	25	11 (9/2)	67	25
Field trial 2 (player N=9)				
A1	63	4 (3/1)	16	21
Total	63	4 (3/1)	16	21

Table 1. Log data from field trials

On average each player completed almost 3 chores in field trial 1, and 7 in field trial 2. In the *tournament* phase, the increased number of game arenas clearly led in to greater involvement in gameplay in the form of more locations being conquered (67 vs 16) and more boss fights being started (11 vs. 4). The amount of items bought in both field trials was similar (25 vs 21). Details on game log can be found from table 1.

Player Engagement

We assessed player engagement by using the Game Engagement Questionnaire (GEQ) [29]. The questionnaire is divided on the topics of *absorption*, *flow*, *presence* and *immersion*.

Absorption (Abs)	Q1: I felt scared. Q2: I lost track of where I was. Q3: I felt different. Q4: Time seemed to stand or stop. Q5: I felt spaced out.
Flow (Flo)	Q7: I could not tell I was getting tired. Q8: When someone talked to me I did not hear them Q9: I felt like I could not stop playing. Q10: The game felt real. Q11: I got excited. Q13: I did not have to think how to play. Q14: Playing made me feel calm.
Presence (Pre)	Q15: Things seemed to happened automatically. Q16: My thoughts were fast. Q17: I played longer than I intended to Q18: I lost track of time.
Immersion (Imm)	Q19: I was really into this game

Table 2. GEQ [29] items used in our questionnaire.

Two questions of the original, Q6 and Q12, were left out for brevity, and in order to avoid language issues, Q11 was rephrased from "I get wound up" to "I got excited". Table 2 contains the items from GEQ we used. Altogether 4 questionnaires were discarded due to incompleteness (final N=14). In addition to the GEQ.

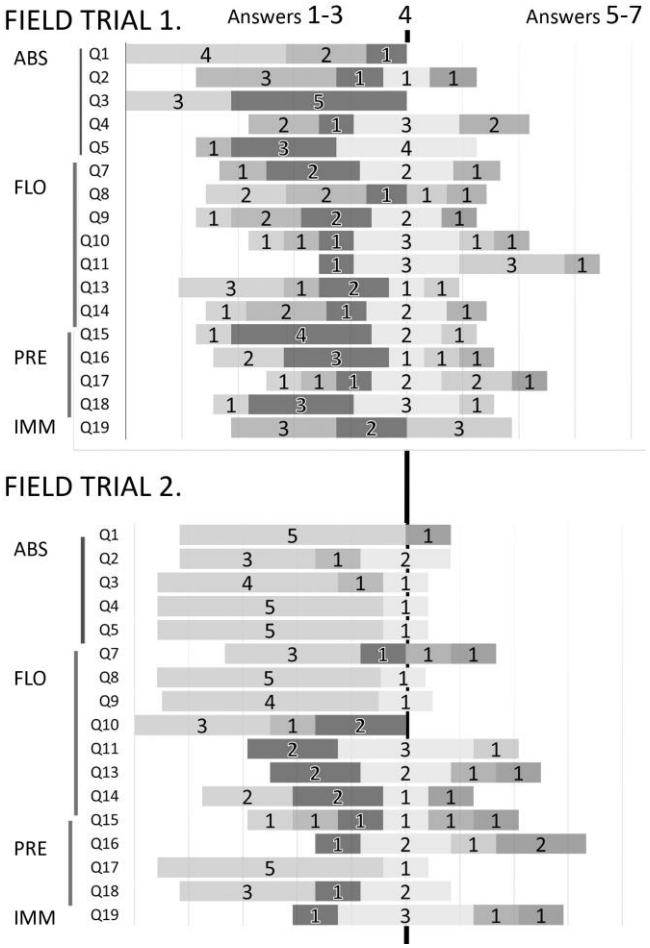

Figure 6. Diverging chart showing the GEQ results from both trials. The Likert scale was from one to seven, where one means the correspondent strongly disagrees with a statement and seven signifies strong agreement. The diverging line is at 4: neither agree nor disagree.

On both trials there were more answers at the very low end of spectrum in GEQ items. The questionnaire also included 9 open questions on the topics of in-game communication, gameplay, and used strategies.

Player Behavior by the Displays

The open questionnaires answers and field notes went through eclectic coding. The topics of the questions defined the categories of the codes. In their questionnaires the players reported an equal amount of group and individual strategies, although from observational data it became apparent that teams devised strategies such as splitting up initially to cover as much ground and do as many chores as possible. However, after a while they learned to come together again once the final battle was about to begin.

All players were given an introduction to the game and its mechanics prior to starting a session. However, many players still approached the study staff for further instructions during game time. Players were active in communicating with one another, and the situated display especially served as a social hub during the tournament phase of the game.

In both field trials, the situated displays worked as social hubs bringing the players together. Conversations were very lively, especially in situations where the players experienced difficulties in defeating the final opponent. The game context itself offered a solid basis for discussion and the fact that the team was working towards a shared goal inspired camaraderie and peer support.

As the game mechanics dictate that it is faster to conquer locations in order to force the final opponent to appear with co-located players, it was interesting to see players dispersed to different corners of the available space. Often, the group would split in order to accomplish more chores, but quickly come together for the final battle as they tried to be the first team to engage the opponent in battle before other teams could do so, or before the game time was over.

DISCUSSION

Campus Knights as a Social Platform

The study presented in this paper strengthens the pre-existing notion on that situated public displays can be used as social hubs around which players gather to collaborate on shared tasks such as defeating the final opponent in a game. Similarly, the requirement to forage the physical environment for items or in-game currency is a powerful motivator for players to collaborate by negotiating various strategies such as splitting up to cover more ground and beat other teams to the punch for the final boss battle.

Campus Knights as a Window on World

Campus Knights utilizes a hybrid model where in-game operations are split between the physical and the virtual worlds. This design effectively combines the best of two worlds: pervasive games such as geocaching remain very popular as they encourage playful exploration of everyday lived environments; simultaneously, casual gaming has seen an unprecedented explosion as smartphones offer everyone the capability to engage in a game.

Utilizing situated public displays as *a window on world* offers novel possibilities that have not been sufficiently explored in previous literature: the possibility to access the virtual replica of the physical world enables engaging and playful scenarios that elevate gameplay to a new level. In the case of *Campus Knights*, players are offered the possibility to transform their everyday campus into an exciting battleground where a team of heroes can go up against an adversary and collaborate to defeat it. Of course, the field trials discussed in this paper were conducted in quite spatially restricted area and the players did not find the game very engaging. Though, it will be interesting to see how a future adaptation of the game will be played in a much larger scale at the downtown area of the city, with tens of players and bigger teams.

CONCLUSION

Campus Knights transforms an everyday space such as a university campus into a game arena, where players move in the physical space to explore areas and discover hidden treasure, which will allow them to access the virtual world to jointly defeat a final opponent. The game utilizes situated public displays as a *window on world*. The introduction of a virtual replica of the physical environment enables engaging "what if" experiences and helps people explore their surroundings in new, imaginative ways.

We suggest enhancing the social aspect of similar games by utilizing public displays to create a pseudo-immersive virtual space. The displays can bring variability to game setup, but they do not necessarily add to player engagement as the players in our two field trials did not find the *Campus Knights* game engaging. However, results from the two field trials confirm that situated displays can serve as a social hub around which players gather to collaboratively accomplish game objectives.

We are currently working on porting the game to outdoor urban setting. This will enable us to offer more screens as WoW, and include teams with more players. Bigger teams and wider game area will hopefully further highlight the strategies players adopt and further enable us uncover more emergent social behavior. During this study we targeted player engagement throughout the whole game, but in the future we will separate the different phases of *CK* gameplay and altering levels of realism on the view into the virtual reality to allow us to do a better comparison between factors in player engagement and co-presence while pervasive displays are used as WoWs.

ACKNOWLEDGMENTS

This research was in part funded by Open Innovation Platforms spearhead project of the Six City Strategy funded by the ERDF and the City of Oulu. In addition, the Strategic Research Council at the Academy of Finland is acknowledged for financial support of the COMBAT project (293389).

REFERENCES

1. Jeanne H. Brockmyer, Christine M. Fox, Kathleen A. Curtiss, Evan McBroom, Kimberly M. Burkhart, and Jacquelyn N. Pidruzny. 2009. The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology* 45, 4: 624–634.
2. Grigore C. Burdea and Philippe Coiffet. 2003. Chapter 1: Introduction. In *Virtual Reality Technology* (2nd ed.). Wiley-IEEE Press, 1–15.
3. Shira Chess. 2014. Augmented regionalism: Ingress as geomediated gaming narrative. *Information, Communication & Society* 17, 9: 1105–1117.

4. Florian Daiber, Marco Speicher, Sven Gehring, Markus Löchtefeld, and Antonio Krüger. 2014. Interacting with 3D Content on Stereoscopic Displays. *Proceedings of The International Symposium on Pervasive Displays*, ACM, 32–37.
5. Andrea De Lucia, Rita Francese, Ignazio Passero, and Genoveffa Tortora. 2009. Development and evaluation of a virtual campus on Second Life: The case of SecondDMI. *Computers & Education* 52, 1: 220–233.
6. Alun Evans, Marco Romeo, Arash Bahrehmand, Javi Agenjo, and Josep Blat. 2014. 3D graphics on the web: A survey. Computers & Graphics 41: 43–61.
7. Jennica Falk and Glorianna Davenport. 2004. Live Role-Playing Games: Implications for Pervasive Gaming. In *Entertainment Computing – ICEC 2004*, Matthias Rauterberg (ed.). Springer Berlin Heidelberg, 127–138. Retrieved from
8. Steven Feiner, Blair MacIntyre, Marcus Haupt, and Eliot Solomon. 1993. Windows on the world: 2D windows for 3D augmented reality. *Proceedings of the 6th annual ACM symposium on User interface software and technology*, ACM, 145–155.
9. Brian J. Gajadhar, Yvonne A. W. Kort, and Wijnand A. IJsselsteijn. 2008. Shared Fun Is Doubled Fun: Player Enjoyment as a Function of Social Setting. In *Fun and Games: Second International Conference, Eindhoven, The Netherlands, October 20-21, 2008. Proceedings*, Panos Markopoulos, Boris Ruyter, Wijnand IJsselsteijn and Duncan Rowland (eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 106–117.
10. Maurizio Caon, Elena Mugellini, and Omar Abou Khaled. 2013. A pervasive game to promote social offline interaction. *Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication*, ACM, 1381–1384.
11. Philip Geiger, Marc Schickler, Rüdiger Pryss, Johannes Schobel, and Manfred Reichert. 2014. Location-based mobile augmented reality applications: Challenges, examples, lessons learned. 383–394.
12. Jukka Holappa, Tommi Heikkinen, and Elina Roininen. 2013. Martians from outer space: experimenting with location-aware cooperative multiplayer gaming on public displays. *Proceedings of the 12th International Conference on Mobile and Ubiquitous Multimedia*, ACM, 53.
13. Kuo-Lun Hsiao and Chia-Chen Chen. 2016. What drives in-app purchase intention for mobile games? An examination of perceived values and loyalty. *Electronic Commerce Research and Applications* 16: 18–29.
14. Staffan Jonsson, Markus Montola, Annika Waern, and Martin Ericsson. 2006. Prosopopeia: experiences from a pervasive Larp. *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*, ACM.
15. Vlasios Kasapakis and Damianos Gavalas. 2015. Pervasive gaming: Status, trends and design principles. *Journal of Network and Computer Applicati*ons 55: 213–236.
16. Heinz K. Klein and Michael D. Myers. 1999. A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS quarterly*: 67–93.
17. Vassilis Kostakos and Timo Ojala. 2013. Public displays invade urban spaces. *IEEE Pervasive Computing*, 1: 8–13.
18. Dongwoo Lee, Jae-In Hwang, Gerard J. Kim, and Sang Chul Ahn. 2011. 3D interaction using mobile device on 3D environments with large screen. *Proceedings of the 13th International Conference on Human Computer Interaction with Mobile Devices and Services*, ACM, 575–580.
19. Kiryong Ha, Zhuo Chen, Wenlu Hu, Wolfgang Richter, Padmanabhan Pillai, and Mahadev Satyanarayanan. 2014. Towards wearable cognitive assistance. *Proceedings of the 12th annual international conference on Mobile systems, applications, and services*, ACM, 68–81.
20. Jaana Leikas, Hanna Strömberg, Veikko Ikonen, Riku Suomela, and Juhani Heinilä. 2006. Multi-user mobile applications and a public display: novel ways for social interaction. *Pervasive Computing and Communications, 2006. PerCom 2006. Fourth Annual IEEE International Conference on*, IEEE, 66–70.
21. Dale Leorke. 2014. Location-based gaming apps and the commercialization of locative media. *Mobility and Locative Media: Mobile Communication in Hybrid Spaces*: 132.
22. Christian Licoppe and Yoriko Inada. 2006. Emergent Uses of a Multiplayer Location-aware Mobile Game: the Interactional Consequences of Mediated Encounters. *Mobilities* 1, 1: 39–61.
23. Petri Luojus, Jarkko Koskela, Kimmo Ollila, Saku-Matti Mäki, Raffi Kulpa-Bogossia and Tommi Heikkinen. 2013. Wordster: collaborative versus competitive gaming using interactive public displays and mobile phones. *Proceedings of the 2nd ACM International Symposium on Pervasive Displays*, ACM, 109–114.
24. Aditi Majumder and Behzad Sajadi. 2013. Large area displays: The changing face of visualization. *Computer*, 5: 26–33.
25. 2014. *Meshmoon Rocket client*. Adminotech Oy. Retrieved Sep. 9, 2015 from http://www.meshmoon.com/Download.aspx

26. Markus Montola. 2011. A ludological view on the pervasive mixed-reality game research paradigm. *Personal Ubiquitous Comput.* 15, 1: 3–12.
27. Michael D. Myers and Heinz K. Klein. 2011. A Set of Principles for Conducting Critical Research in Information Systems. *Mis Quarterly* 35, 1: 17–36.
28. Kenton O'Hara. 2008. Understanding geocaching practices and motivations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 1177–1186.
29. Aaron A. Reed, Ben Samuel, Anne Sullivan, Ricky Grant, April Grow, Justin Lazaro, Jennifer Mahal, Sri Kurniawan, Marilyn A. Walker and Noah Wardrip-Fruin. 2011. A Step Towards the Future of Role-Playing Games: The SpyFeet Mobile RPG Project. *AIIDE*.
30. Peter A. Smith. 2015. Augmenting Reality in Sensor Based Training Games. In *Virtual, Augmented and Mixed Reality*, Randall Shumaker and Stephanie Lackey (eds.). Springer International Publishing, 329–336.
31. Ivan E. Sutherland. 1968. A head-mounted three dimensional display. *Proceedings of the December 9-11, 1968, fall joint computer conference, part I*, ACM, 757–764.
32. Ville H. Tuulos, Jürgen Scheible, and Heli Nyholm. 2007. Combining web, mobile phones and public displays in large-scale: Manhattan story mashup. In *Pervasive Computing*. Springer, 37–54.
33. Oliver Dirk Storz. 2008. A Distributed Systems Infrastructure for *Open Public Display Research Networks*. (Doctoral dissertation).
34. Tamas Vajk, Paul Coulton, Will Bamford, and Reuben Edwards. 2008. Using a mobile phone as a "Wii-like"-controller for playing games on a large public display. *Int. J. Comput. Games Technol.* 2008: 1–6.